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Architectural Engineering and Executive Design: Modeling Procedures, Scientific Tools, Simulation Processing

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Abstract — The study is part of the scientific references on *executive design* in engineering and architecture, understood as an interdisciplinary field aimed at anticipating and simulating, planning and managing, guiding and instructing construction operations on site. On this basis, the study intends to provide an analysis of a theoretical, methodological, and guiding character aimed at constituting the disciplinary sphere of the *executive design*, often in the absence of supporting methodological and procedural guidelines in engineering and architecture. The basic methodologies of the study refer to the investigation of the theories and references that can contribute to constituting the scenario of the *executive design* as the practice of modeling, visualization, and simulation of the construction phases, through the practices of projection of the pragmatic issues of the building. This, by proposing a series of references, interrelations, and openings intended to support (for intellectual, procedural, and applicative purposes) the executive definition of the project, aimed at activating the practices of cognitive acquisition and realization intervention within reality.

Keywords—Modeling and Simulation Technology. Executive Design. Discretization of the Construction. Engineering Design for Building.

I. Introduction

IN the scenario under examination, the design orientation is treated with respect to the cognitive, exploratory and recursive dimension, in which the *executive design* is defined as a methodological compartment correlated to the instances and objectives aimed at the real feasibility and practical implementation of the architecture: that is, as a context directed towards the operative constitution, as a practice aimed at the planning and coordination, management (cognitive and instrumental) and control of the contents, phases and information directed to the production and construction of the building and its parts. The configuration of the contents of a productive and constructive nature is addressed through the practices of "presentification" (in the absence of "sensible presence" of the construction) and of "formal transcendence" of reality according to the elaboration and exploration that are outlined in "technological action", with the development and application of both technological and instrumental "prostheses", aimed at knowledge and action, and of strategies and devices to face and "dominate", "artificially" and "technically", the reality of reference. The elaboration of the project then becomes explicit as a praxis of "instrumental acting" and "rational acting", according to the action directed at translating logically conceivable possibilities into "factual reality", through the formulation of the instruments, conceptual and operational, in a cognitive, exploratory and active form, aimed at interacting with reality. As a concluding statement, this is revealed in the technical procedure of "rational foresight" (with a "temporal" and, therefore, "promethean" function) to arrange, organize and anticipate both the realization and management phases, arriving at the implementation of a model of reality that does not yet exist, according to the integration of "communicative functions" and "orientation functions", i.e., guidance and instruction for concrete action, established on "precision" practices to address the "application to reality". Furthermore, the analysis considers the executive representation according to the forms of the "linguistic symbolization" and the support of the "metaphorical" and "scientific" language of the *executive design* (as a practice of "decoding" and "structuring" the reality).

II. The Procedures for the Analytical and Operational Processing of the Architectural Engineering Design

The study of the *executive design* of architecture examines the methods of formulation of the devices required for the achievement and knowledge of the productive, constructive and procedural reality, in accordance with the instrumental and analytical character of the technical drawings. At the same time, the study considers the modalities of visualization, prefiguration and communication of the technical and constructive contents of the project, according to the instrumental and operational character of the executive drawings. The analytical and operative characters define the constitutive aspects of the executive representation, in general, and of the executive drawings, in particular, adopting and explaining the production and construction procedures, the identification and early control of the building processes, the simulation, through experimental forms, of the phases of installation and assembly of the architectural organism and its parts (Fig. 1).

The executive representation of the project is structured both according to the practices of knowledge and acquisition of what has been arranged and made possible by the productive, constructive and procedural reality of reference, and according to the practices of expression and instruction of the contents and information required for logical and operational coordination, control, checking and effective implementation. The executive representation is articulated as a cognitive and experiential

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process, as an expression of the operational and instrumental rationality involved in the implementation of technical processes, through the development of the drawings in the form of "executive models", replacing the "real phenomenon" (i.e., the construction of architecture) with its own interpretative synthesis: the drawings become the "model of reality", proposing themselves as the logical schemes through which to give meaning to the complex set of appearances with which reality presents itself.

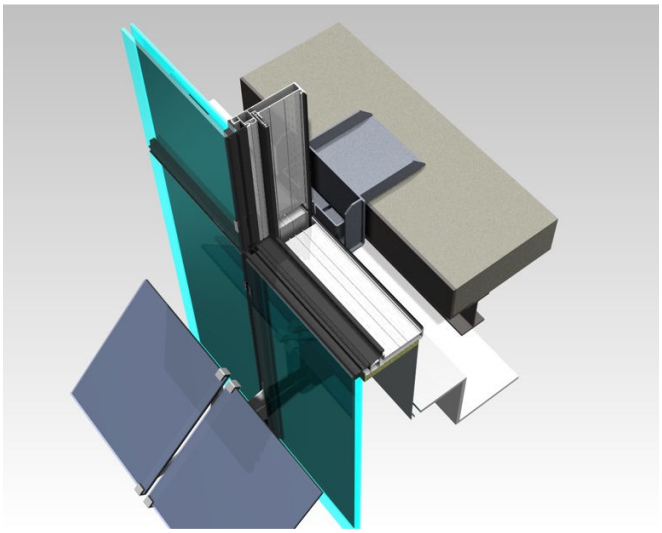

Fig. 1. Sidell Gibson Architects, *One Snow Hill* Building, Birmingham (© Courtesy of Focchi).

The executive representation is outlined as a process of simulation of productive and constructive reality, through the graphic-descriptive drafting of works in the form of analytical and operational tools (as a set of interpretative hypotheses formulated to establish a strategy of action), allowing to perform on the image the same constructions that should be made in space, as if they were really performed (Fig. 2) [1].

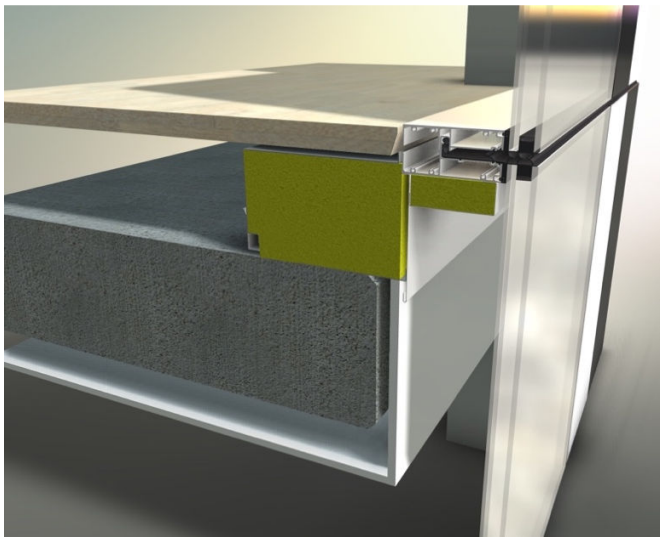

Fig. 2. Stefano Boeri Architetti, *RCS - Media Group Headquarters*, "A2" Building, Milan (© Courtesy of Focchi).

The practical application takes place as the drafting of "executive models" of the actual reference reality, studied in the form of "schemes of action" for the intervention towards reality itself considering:

- the representation as an awareness of reality (as appropriation of data) according to the criteria of analytical tools;
- the prefiguration of the result of the design/constructive act, according to the criteria of the operational instrumentation.

The practical application aimed to the development of the executive models, in their instrumental analytical meaning, is concretized as simulation of an external reality, to be "understood" in an intellectual synthesis and as a procedure for the construction of interpretative models of reality (becoming, at the same time, a critical hypothesis of knowledge of the existing). Within this examination, the executive representation is determined according to the use of graphic signs that constitute configurations capable of simulating the object to which it is intended to refer, involving the expression of the analytical drawings in the form of "models" (here described as "interpretative" of the reference reality) of a system of relations.

The analytical instrumentality of the executive drawings of the project, through the graphic-descriptive drafting of the contents related to the productive, constructive and procedural reality, leads to the examination of reality as a form of "experiential observation" and "discretization" that is subjected to the work of "revelation" and simulation (according to the modeled visualization of the architectural organism and its parts, construction systems, components, technical elements, materials and their physical, dimensional and connective relationships).

The practical application directed to the development of the executive drawings, in their operational instrumental meaning, observes the complexity of the productive and constructive reality that can be represented and ordered through the development of "models" consistent with the morphological, geometric, dimensional, physical and connective specificity of the architectural organism and its parts. The operative instrumental meaning of the executive drawings, capable of simulating reality up to the comprehension of the rules and procedures both productive and constructive, is developed according to the "analogical" representation methodology performed as the construction of interpretative schemes of properties that cannot be evaluated through direct vision, but through different logical references: this according to the recognition of what is fixed in the "essence of reality", assuming a language that acts as a *medium* of understanding through a process of "artificial mediation" (Fig. 3).

The practical application concerns the analytical and operational instrumentality of the executive drawings through the graphic-descriptive drafting of the devices capable of visualizing, simulating and communicating the contents and information for the actual realization, focusing on the interface and connection conditions between the construction systems, components, technical elements and materials. In this regard, the executive processing includes the procedures able to identify, control and indicate (in simulative and communicative form, through a series of graphic-descriptive conventions) the pragmatic issues of the project (Fig. 4).

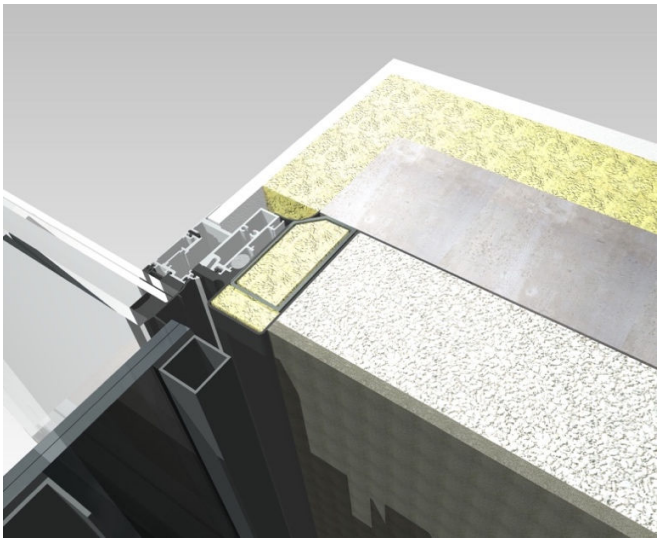

Fig. 3. Gianandrea Barreca and Giovanni La Varra, *RCS - Media Group Headquarters*, "B5" Building, Milan (© Courtesy of Focchi).

Fig. 4. *Ingenhoven Overdiek und Partner*, *Lufthansa Aviation Centre*, *Frankfurt Airport*, Frankfurt (© Courtesy of *Ingenhoven Overdiek und Partner*).

The analytical and operational tools, in addition to becoming the means of explaining the productive and constructive reality and its procedural contents, involve, in general, the development of:

- the cognitive and explorative potential through which it is possible to understand, visualize and explain reality itself, intended as a study of what is available and feasible and as a process of projection, forecasting and simulation;
- the modes of planning, governing, checking and guiding the production and construction phases, as a logical constitution of operations in succession, through the "modeled" and schematic transposition of the contents and sequences directed to the building of the architectural organism and its parts;
- the modes the project is structured, so that the graphic-descriptive documents can detect, explain and visualize all the productive, constructive and procedural information: this in accordance with the use of strategies (also based on the normative apparatus) aimed at developing a language and a code on conventions and prescriptions necessary for the unequivocal transmission of the data (Fig. 5) [2].

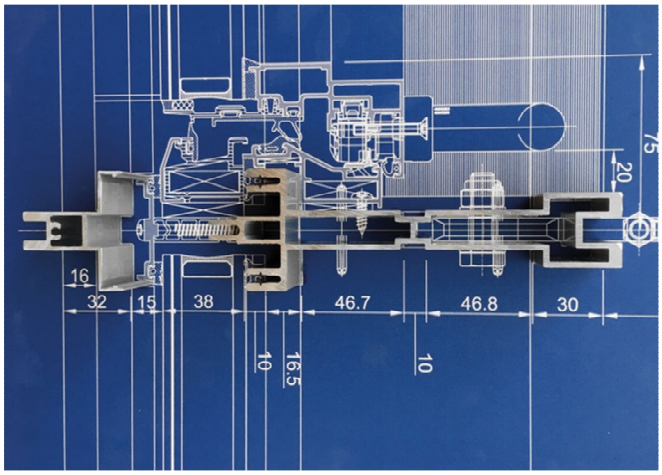

Fig. 5. Renzo Piano Building Workshop, *École Normale Supérieure (ENS)*, Paris-Saclay (© Courtesy of Renzo Piano Building Workshop).

The analytical and operational tools of the executive drawings are highlighted according to the prefiguration of both the possibilities (i.e., as "anticipation of possibilities") and the implementation methods determined and allowed by the production and construction techniques: the means of representation and modeling are expressed as supports capable of being perceptively "similar to reality" (described in the form of an assert which, by specifying what is represented, makes it possible to derive empirical inferences).

The models are intended to express what is provided by the reality of reference and to indicate the constitutive modalities of the project, involving the "reproduction", in simulative form, according to:

- the representation of an "extrinsic" character, related to the objective of visualizing the morpho-typical, physical, geometrical, dimensional and connective factors of the devices that contribute to the production and construction of the overall and specific parts between systems, components, technical elements and materials;
- the representation as "mediation", arranged in a relational and interactive form between the cognitive and operational process carried out by the executive process, providing a "replacement" of direct experience. In this regard, the representation is aimed at "mediating" or even completely "replacing" the physical interaction with experiential reality, observing its contribution to the procedures for communicating information and operational instructions for the action;
- the integration of "communicative functions" and "orientation functions", i.e., guidance and instruction for the effective action towards the productive and constructive reality of reference (Fig. 6) [3].

Fig. 6. Massimiliano Nastri, *Tecnet* Headquarters, Milan (© by the Author).

III. The Procedures for the Engineering and Executive Design

The development and analysis (as a process of understanding and transmission into the productive and constructive reality) of the *executive design* observe, in synthesis, the constitution of the graphic-descriptive contents according to:

- the implementation of tools for "interaction" and "mediation" with respect to operators, professionals and technicians, specifically, with respect to the production and construction tasks involved. The "executive models" are intended as "artificial means", as "machination" tools, since they do not immediately operate to achieve the productive and constructive aim, but follow a "mediated" procedure: these devices are not only expressed as "artifact tools" but also as "artificial procedures", i.e., intended as "artifices" and "expedients" for the acquisition of the contents related to reality;
- the identification of the means and instruments for guiding and checking the building phases, as an expression of a "decision-making process" that includes the contents and procedures of information, description and control, including technical prescriptions (Fig. 7).

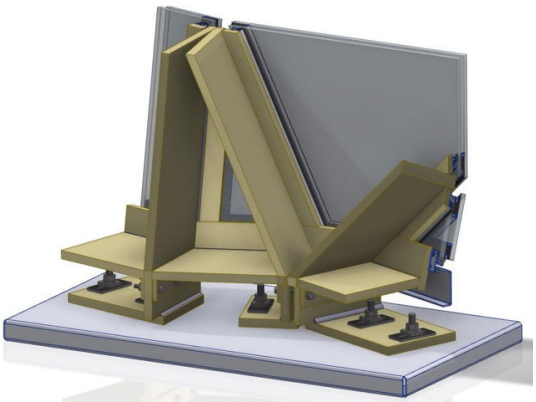

Fig. 7. SimpsonHaugh and Partners, *Dollar Bay* Building, London (© Courtesy of Focchi).

The executive representation becomes the intermediate between the design contents and the consequent building, assuming the double function of language and code and allowing to decode the productive, constructive and procedural aspects. Specifically, the development of the executive drawings in the form of "measurable and available models" (representing the reality of reference), according to their analytical and instrumental aspect, is proposed as a means to substitute the effective physical manipulation and the "material action" inherent in production and construction processes: and the codified language that typifies the executive drawings is defined through forms of "linguistic symbolization" (expressed through symbols, codes and graphic-descriptive schemes) for the explanation, prediction and simulation of the building contents and specific operations (Fig. 8) [4].

Fig. 8. Executive model representing the productive, constructive and procedural aspects (© Courtesy of Schüco).

The modeling and simulation procedures implemented by the *executive design* of the project (for which the representation of reality constitutes an essential condition to guide its generation) are expressed as "language of acting in reality", through a language capable of acquiring "substance", as "indicative" and "metaphorical" language. The language that defines the executive representation thus determines the technical drawings according to:

- the constitution of instruments of explanation and prediction capable of expressing the condition of the objectifying perspective of the project which is specified as a form of abstraction and artificialization. In this regard, the purpose of scientific language consecrates the duality of *theoría* and *práxis*, for coherent explanation and effective application;
- the application of a "scientific" language, managed by the relationship between "expression" and "signification", i.e., according to the operability aimed at "meaning" and at "designating the action", pointing out the correspondence

between knowledge and intervention towards and within the constructive reality (through the use of a conventional, codified and instrumental system of signs) (Fig. 9).

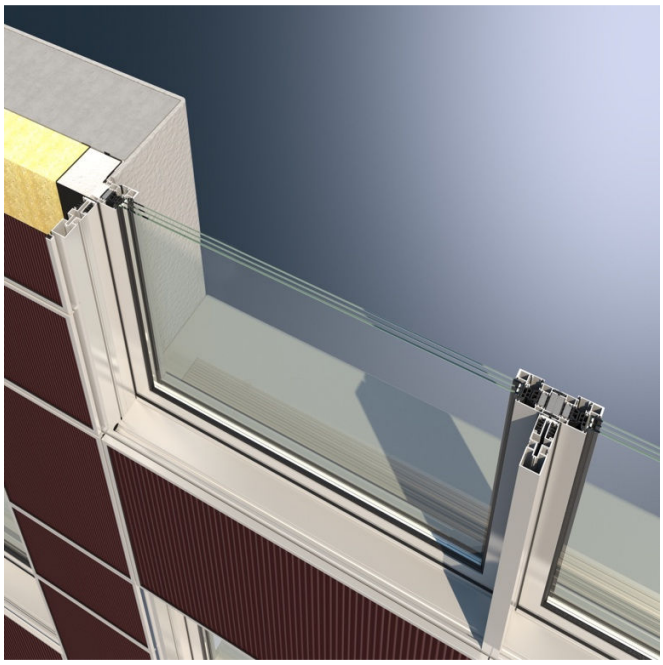

Fig. 9. Modeling and simulation procedures (© Courtesy of Schüco).

The conception of tools for knowledge and action towards the reality of reference focuses on the drafting of design devices able to provide and communicate the indications for the building of the architectural organism and its parts. The development implies the practices of constitution of "executive models" able to "build", in the form of "analogical representations", the pragmatic conditions of the project according to the support of codified visualization techniques and "linguistic symbolization" in order to communicate the productive and constructive information: the executive development acknowledges the criteria peculiar to the "communicative action" expressed in the operative language aimed at "decoding" and "structuring" the reality of reference. This study involves the use of techniques of "factual" representation and "coding" of productive and constructive meanings, specified and detailed according to the set of rules, conventions and graphic-descriptive prescriptions.

The modeling and simulation procedures provided by the *executive design* are implemented according to the application of the "scientific", symbolic and coded modes of the representation and communication for the visualization and control of production and construction phases. In this regard, the development of the *executive design* is drafted according to an "indicative" and "metaphorical" language, aimed at synthetic information and practical application, able to expose the real substance of what is represented and explained. The *executive design* thus complies with a set of rules, codified conventions and some particular graphic-descriptive features that are offered as a technique for the communication of project information. In this context, the definition of "rhetoric" and regulations of the executive drawings takes place in the form of a system of prescriptions; in any case, the development of a system of means and procedures of communication concerns:

- the reference to a particular type of representation considered as a "metalinguistic" operation that develops a "rhetoric", that is precisely a system of criteria intended for the practice of drafting the executive models;
- the technique of exhaustive communication of design information, which is structured in a precise methodology of internal references, such as to guarantee the completeness of understanding [5].

The analytical and operational instrumentality of the executive drawings is provided with respect to the procedures of knowledge and "possessing" of reality (through a process of observation, abstraction, decoding and discretization of reality), considering the criteria of modeling and representation as means of knowledge and expression, intended in the support towards the relationship with the physicality of the material to be formed. Therefore, the examination, the "discretization" and the knowledge of the reality of reference, which becomes "possessed", are developed through the executive drawings defined in their analytical instrumentality: they are implemented, according to the disciplinary objectives, through the modeling and representation of both the constitutive elements of the architectural organism and its parts, and of the productive and constructive modalities (which are thus achieved at a cognitive, anticipated and simulated level). On these bases, the reality of reference is "objectified" according to the criteria of the executive representation which means to reveal the productive and constructive matters, specified with respect to the components, technical elements and their interfaces, "assigning" the effective physical, geometric, dimensional, material and connective conditions (Fig. 10).

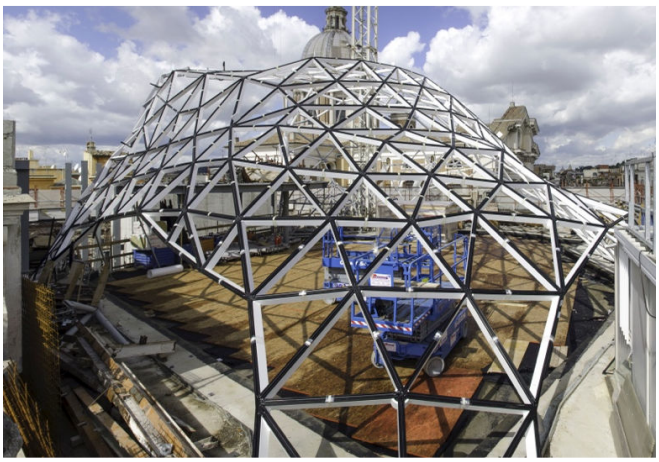

Fig. 10. Massimiliano and Doriana Fuksas, *ex Unione Militare*, Rome (© Courtesy of Pichler Projects).

IV. The Coding Procedures of the Executive Design

The *executive design* is conceived as a method able to adopt and integrate, through specific modes of representation, the requirements of the productive and constructive reality of reference (which, according to the processes of graphic-descriptive visualization, is "discretized", "revealed" and "objectified"). In this regard, the study focuses on:

- the comparison with the effective reality, domain of possible transformations, in which the physical entities are the necessary prerequisite for any design operation;
- the phenomenological understanding of the architectural event conducted through the appearances of reality. This methodological approach implies the *constructibility* of architecture as a moment of verifying and control of the design process and as a connection between the programmatic instances, configured in specific compositing frameworks, and the congruity of the same to the available technological systems;
- the procedures of expression, visualization, representation and communication of the executive contents, which are demonstrated through the analytical instrumentality of the models aimed at observation, discovery and knowledge, assuming and explaining the conditions of feasibility and "executability", through the "prevision" understood as "visual foretelling" of the built architecture (Fig. 11).

Fig. 11. Renzo Piano Building Workshop, *MUSE*, Trento (© Courtesy of Pichler Projects).

The executive representation is dealt with as tool of simulation, as well as with operational forecasting instruments of the productive and constructive reality, while the contents explain the structure of "analogical images" specified in a cognitive and active form. The executive drawings are defined as "models". (i.e., in the form of "logical-instrumental models") for knowledge and action, supported as:

- the devices for detecting the contents and procedures of true reciprocity between the executive representation and reality, aimed at highlighting, in addition to measurability, the respective relations between the elements that constitute the architectural organism (i.e., according to the effective conditions provided by the productive, constructive and procedural reality);
- the devices of cognitive acquisition and action towards reality, where the representation therefore consists in making evident an "absence" (referring something that owns its own reality, code and recognizability);
- the devices of simulation reality according to the "building condition" which allows to know reality in its "structural constitution", according to the work, intellectual and practical, to imprint in the graphic-descriptive documents the specific semantic values aimed at determining representation as a means of exploration, expression and communication (Fig. 12) [6].

Fig. 12. Renzo Piano Building Workshop, *MUSE*, Trento (© Courtesy of Pichler Projects).

The executive representation, through the use of "linguistic symbolization" techniques, considers the use of schemes and codes by the graphic-descriptive supports adopted in order to explain both the contents and the specific productive and constructive operations. In particular, the observations on the "perceptual achievement" (assimilated to a process of "decoding" the reality of reference) implies:

- the "acquisition of meaning" (which occurs as a consequence of the effective "structuring", with respect to the productive and constructive reality) expressed by the executive drawings;
- the operative instrumentality, arranged by the executive representation of the project, which involves the definition of the graphic-descriptive procedures capable of formalizing the indications and information for the building of the architectural organism and its parts (Fig. 13).

Fig. 13. Future Systems, Andrea Morgante, *Enzo Ferrari Museum*, Modena (© Courtesy of Pichler Projects).

The executive representation of the project is performed in the form of a codified communication system able to detect the constructive and procedural contents with respect to:

- the communication of a set of data for the right execution of the building, according to a procedure in which the effort is here to adhere to a set of institutionalized symbols, with the meaning of precisely known code, but whose decoding system is as secure as possible, ensuring maximum univocity to the message that is communicated;
- the support of "symbolic indications", which break their direct link with geometry as a representation by sections and projections of a given object, to turn on the one hand towards the simple reference - notation to the material as a pre-existing semi-format (as well as semi-finished), on the other hand towards the definition of the conditions of localization and relation of the object, of the possible cases (more than one) of its relation. And this typology of development aims to become a highly symbolized representation, endowed with its own necessity of invention in a situation of its own nature of material for architecture.

The information features of the executive representation are intended as the communication of a data system for the purpose of a right implementation: the work, aimed at the production and construction phases, adopts a "notational system" as an essential identity to compare with the effective execution. The executive representation includes the development of determinate and exact indications, especially in relation to the methods of visualization and expression required by contemporary production and construction solutions, through a system of codes and symbols able to articulate, in synthetic form, the different levels of detail, general and specific information, references to technical procedures and interfaces. The principles of development foresee, therefore, the knowledge of the analytical and instrumental modalities of explanation and identification of the productive and constructive contents, through the adoption of "known signs", according to:

- the need to translate the contents of the *executive design* into geometric, dimensional and material recommendations and into construction techniques in use;
- the interpretation of the contents into a "communicable message", providing for the combination of the aspects aimed at indicating the operating instructions;
- the procedure that foresees the reality of the finished project, describing it in its internal structure, specifying every detail so that it can be built exactly as it is described;
- the procedure aimed at expressing the operability directed to the architectural organism, intended as a process capable of explaining, before production and construction phases, all the executive implications of each part of the building.

The constitution of the "executive models" involves the adoption of extremely controlled representative criteria, so as to be, themselves, an expression of technical precision (in order to reduce possible misunderstandings) and the hierarchical use of the graphic-descriptive signs. In this regard, the development is aimed at detecting the geometrical lines, alignments and preferential geometrical and interface configurations, till to define the "spatial measures" of the building (referred to the effective physicality of the construction systems, components and technical elements, according to the objectives directed to the check, control and operational implementation of the contents) (Fig. 14) [7].

Fig. 14. Future Systems, Andrea Morgante, *Enzo Ferrari Museum*, Modena (© Courtesy of Pichler Projects).

The *executive design* of the architecture, therefore, implies as contents and objectives:

- the development of documents without failures, such as communication errors, omissions of information, non-coordination between thematic areas, which can be removed through a control activity and the adoption of rules for the drafting of an appropriate and efficient reporting system;
- the thematic development of the documents, i.e., that move towards homogeneity according to the operational subdivision of the executive phases;
- the specialization of the documents in containing the information related to the qualitative and quantitative characteristics of each technical element, the indications related to the assembly methods, the localization and positioning of each technical interface;
- the aggregation and interaction of the documents according to the specific terms of use and interpretation by the expertise and professionals in charge, to minimize the risk of misinterpretations (Fig. 15) [8].

Fig. 15. Future Systems, Andrea Morgante, *Enzo Ferrari Museum*, Modena (© Courtesy of Pichler Projects).

V. The Executive Design of the Engineering Interfaces and Construction Phases

The *executive design* examines the technical interfaces as a means of technical-constructive and operational interaction between parts of the architectural organism, defined at spatial level (as a context of connection and integration) and at physical level (as a context of connection for materials, elements, particular morphological configurations and devices required for the building). The study of the technical interfaces is intended as a tool for the operational coordination of the construction, proceeding from the check of the executive feasibility up to the procedures for the building: these are specified with respect to the physical structure (geometric, dimensional, material and productive) of the parts to be connected, to the assembly methods and to the tools and building site equipment.

The processing of the technical interfaces concerns the drafting of the detailed executive models that explore the procedural conditions of the construction sections, starting from the arrangement related to the localization and coordination, according to the type, the methods of connection and assembly (with respect to the systemic organization for sequences and construction tasks) of the building site. The development and executive representation of the technical interfaces are thus oriented to the systemic structure of the architectural organism, its parts and its construction phases. In this regard, the definition of the *executive design* is carried out through the operational planning and organization of the construction phases, in which the analysis of the technical interfaces is achieved through the hierarchical detection of the effective performance (Fig. 16).

Fig. 16. Fletcher Priest Architects, *Angel Court* Building, London (© Courtesy of Focchi).

The methodological orientation considers the "subdivision of the construction problem" with respect to formal, physical, dimensional and connective conditions: this subdivision leads to the development of a series of manufacturing plans for the technical interfaces by means of the visualization and instruction criteria (in graphic-descriptive form) of the connection modes.

The executive development of the technical interfaces is configured as a "tectonic" methodological orientation of the project (in the expression of *architectural engineering* practices), as an expression of the "art of connection" and the detection of the processes of "assembly of parts and techniques", in the reference to the principles of the "poetics of construction" (and the consequent "fragmentation of architecture by problems"). The study of the technical interfaces is carried out as a work of fine-tuning and control of the characters of interaction between the parts of the architectural organism, analyzing their synergies and correspondences: this as the implementation of the logic of "aggregation" aimed at explaining and governing the assembly system, the connections and the executive sequences.

The processing and executive representation concern the achievement of the procedures of graphic-descriptive expression both for the knowledge of the productive and constructive issues and for the communication of the operative modalities for the building. In this regard, the processing and executive representation are defined with respect to:

- the technological culture specified by the figure revealed by the *tekton*, as an expert both in the production and construction solutions and tools for their explanation and visualization and in the ability to articulate, to "manipulate" and to anticipate the means for the "material implementation" of the project;
- the technological culture specified by the figure revealed by the *technítes*, as an expert in the development of the constitutive contents of the project and of the logical and operational coordination tools able to guide the modalities of building of the architectural organism and its parts [9].

The executive processing of the technical interfaces depends on the interaction between the elements, the connections, the intrinsic quality of the materials and the building modes, identifying the production and construction procedures with the "art of construction": therefore, the *executive design* is expressed as a "machination" approach, where the methods of assembly are considered as a "design strategy" (Fig. 17).

The technological culture of the design under examination focuses on the operational process aimed at establishing the logical and "organized order" that structures the architectural organism and its systemic parts, intended as a reference for leading and coordinating the development of the construction sections and the relative methods of building and assembly. In general, the "hierarchical" approach that characterizes the operating procedure is articulated with respect to:

- the "organizational" set, which contemplates the analysis of the contents relative to the parts that build the architectural organism, to be examined and applied as specific themes;
- the "structural" set of the system, which concerns the development of the productive and constructive contents on the basis of the geometrical and functional model.

Moreover, the "hierarchical" approach that defines the operative procedure focuses on:

- the morpho-typical, dimensional and functional coordination, which involves the planned relation between the parties and the executive sequences, laid out in relation to each other and in mutual dependence;
- the coordination of the construction, as an organized set of spatial and technical elements, analyzed and applied in both "organic" (in the relationship between the technological subsystems, components, technical elements and materials) and "unitary" (specific to the executive localization of the single components, technical elements and materials).

Fig. 17. Fletcher Priest Architects, *Angel Court* Building, London (© Courtesy of Focchi).

Specifically, the settlement and systemic coordination, which also concern the subdivision of the construction sequences, involve:

- the study and drafting of the "informative" requirements, according to the analysis of formal, dimensional, performance, physical, structural and connective factors of components, technical elements and materials;
- the study and drafting of the "operational" requirements, according to the analysis of the productive and executive characteristics of the components, technical elements and materials with respect to the real feasibility conditions [10] (Fig. 18).

Fig. 18. EFA, *Collodi Butterfly House*, Collodi (Pistoia) (© Courtesy of EFA).

VI. The Typological and Engineering Procedures for Connective Processes

The "hierarchical" approach of the *executive design* includes the "decomposition" of the qualities (performance, physical, structural, connective and material) and their attribution, both independent and integrated, to the technological subsystems, components and technical elements: in this way, each part has a specific purpose and a distinct position, identified as a whole and in the particular context of the architectural organism (in the reference to the prediction requirement, theorized by Peter Rice, as an expression of the "ability to predict the performance of the system"). The "decomposition" becomes the instrument to study the parts and their reciprocal relations, according to the "organizational structure" of the architectural organism (intended as the "scheme" by which the interconnected parts that build the system are organized).

On this basis, the "organizational structure" expresses the "subdivision model" and "coordination model" to identify and understand the contents and their relationships related to the technological subsystems, components and technical elements (i.e., the elementary organizational subsystems into which the system is divided).

The executive development proceeds with the "decomposition" of a plurality of coordinated and "organized" elements into "subsystems", into "interacting" and "interdependent components". In this way, the executive development of the project is determined with respect to:

- the concept of a "tectonic" and "functional" system" (as a combined aggregation of multiple "structured" and interacting functions): in particular, the functions are assigned in correspondence of a subsystem performed by components and technical elements with "unique function" or "generic function";
- the configuration of a "decomposed system" both in homogeneous contents and procedures and in "phases or equipped sequences", based on the interaction between the technological subsystems, components and technical elements (Fig. 19) [11].

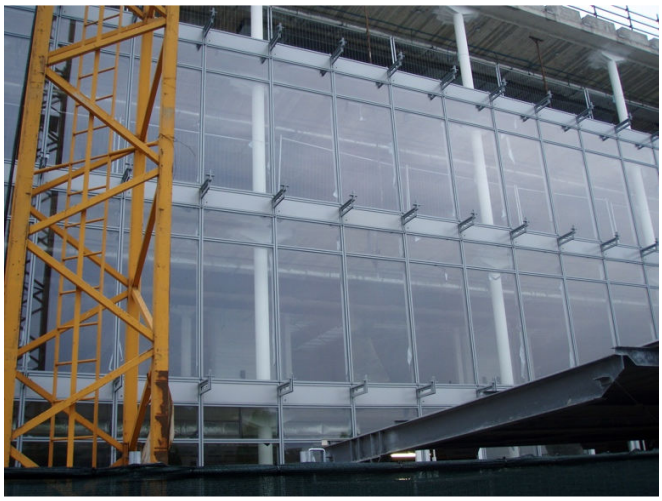

Fig. 19. Maurizio Varratta, *iGuzzini Lab*, Recanati (© Courtesy of Pichler Projects).

The *executive design* involves the identification of the compatibility and co-action requirements between the sub-systems, i.e., between the technological systems, components and technical elements, proceeding through the transformation of the assigned problem into "sub-problems" organized around the overall solution elaborated for the "global problem": and for each of these "sub-problems", the objectives and constraints imposed by the "overall solution" have to be defined.

The *executive design* process implies the systemic and coordination planning of the architectural organism and its parts, according to the synergy of the interface apparatus and the articulation (geometric and dimensional, physical and material, mechanical and connective) aimed at generating specific performances: since the overall performance result is the product of both the performance content of the single objects and the way they interact with each other, it is necessary to specify in advance the performance requirements (single and/or overall) and to design the system model under examination in order that it is organized - before, during and after its implementation - in a selected number of subsystems, capable of providing the foreseen performances, each of them autonomously and/or globally.

In this regard, the *executive design* process examines the possible and essential interactions between the construction systems, components, technical elements and materials for production and construction, in accordance with performance requirements:

- the hierarchical organization of the design contents, according to the geometric-dimensional configuration levels and according to the articulation (or "deconstruction") by technological "sub-systems" (or "sub-problems") and technical interfaces;
- the planning of the operability related to the action (i.e., planning, management and implementation) with regard to technological "sub-systems" (or "sub-problems") and technical interfaces, proceeding towards the "materialization" (or "immersion in material reality") of the project (Fig. 20).

Fig. 20. Maurizio Varratta, *iGuzzini Lab*, Recanati (© Courtesy of Pichler Projects).

The "decomposition" in the elements coordinated with each other and "organized" into "subsystems" leads to detect the architectural organism with regard to a series of specific attributes connected with the logic that configures the design process and that aims, on the one hand, to consider the events in their totality and complexity and, on the other hand, to decompose the design problem in its parts or sub-problems and in the framework of relations able to provide continuous reference to the overall project. The articulation and subdivision of the contents and procedures related to the architectural organism implies that:

- "each part or sub-problem is itself a complex system", which, if on the one hand is part of the design problem, on the other hand can lead to successive decompositions, in an integrated process that has no solution of continuity;
- the components and technical elements are part of a more complex system (or subsystem), related to other similar or different parts but all concurrent with the functioning of the system, corresponding and aligned with the functional system;
- the components and technical elements are similar to a system that can be divided into parts or elements interconnected by a specific framework, defined for the specific requirements [12].

The executive development involves the analysis of the technological subsystems, components and technical elements, observed both in their contiguity and interactions (morphological, physical, dimensional, functional, productive and constructive), and within the general and specific framework of the architectural organism, considering:

- the study of the building parts (which in turn are connected in an "organized" way) and their technical interface modes (consisting of single parts competing to provide a defined value of checkable quality);
- the implementation and control of the interaction criteria between the parties, analyzing their compatibility, synergies and correspondences.

The *executive design* is related to the analysis of the different types of components, expressed with a "simple or elementary" character (i.e., not further divisible), with a "complex or composite" character (which are produced by simple products assembled in a unitary whole), as "intermediate finished products" or as "basic construction elements, simple or complex". These components, subdivided into elementary products ordered within a unitary expression, are analyzed in the "normative" and "objective" perspective, in their compliance with the performance requirements, in the "structural" perspective, in the description of different "syntactical operations" and in the "procedural" perspective, till to the "guiding" procedure to build (Fig. 21) [13].

Fig. 21. Maurizio Varratta, *iGuzzini Lab*, Recanati (© Courtesy of Pichler Projects).

VII. The Systemic and Architectural Coordination Procedures for Connective Operations

The *executive design*, through the "systemic" and "structural" constitution of the architectural organism, proceeds by means of the analysis of the technological subsystems, components and technical elements, according to the "decomposition" by "structural modules" (or "compositional units") and according to the related "aggregation" rules. The technical interfaces between the components, technical elements or materials are examined with regard to the "edges" (of morphological, physical, structural and constructive character) of the parts of the architectural organism to be connected. In this regard, the development examines the ways of connection such as the space where one or more components, technical elements or materials meet and are fixed (or joined), with or without joining devices (or products).

The application considers the criteria by which the ways of connection assume the geometric-dimensional characteristics produced by the relative combination with respect to the "relationship zones" by which the components and elements are explained according to:

- the incorporated joint, where the connection modalities are included in the morphological and technical-constructive composition;
- the separated joint, where the connection modalities are not included in the morphological and technical-constructive constitution, involving the criteria of adding a separate joining device.

The executive development focused on the "relationship zones" (i.e., on the connection modalities) includes the study of the joining devices (or products) according to:

- the procedures of connection between two independent parts of the architectural organism, defined by specific identities and requiring the joining in a permanent form (through the support or absence of additional products) for the performance of specific functions;
- the procedures for the construction of the joints and the production of composite solutions, capable of carrying out functions that the individual units, properly assembled and interacting, contribute to ensure;
- the examination and resolution of the capabilities (at geometric and dimensional, functional and mechanical level) to integrate the categories of tolerances related to manufacturing and assembly processes, in combination with the morpho-typological criteria expressed into the architectural design [14].

The assembly modalities consider how the components, technical elements or materials are related to the "connection zones", identifying:

- the framings with incorporated joint, for which the connection modalities are foreseen in the morphological and technical-constructive structure;
- the framings with a split joint, for which the connection modalities are not foreseen in the morphological and technical-constructive structure, providing the criteria for the insertion of a separate joint entity (Fig. 22).

Fig. 22. Renzo Piano Building Workshop, *Courthouse*, Paris (© Courtesy of Renzo Piano Building Workshop).

The operability is achieved with regard to the concept, drafting and construction of the technical interfaces, examined as a relationship context (geometric and dimensional, technical-constructive and operational), at a spatial level (as a space of connection and integration) and at a physical level (as a space

of jointing for to the presence of elements, materials, particular geometric configurations and devices necessary for the assembly between parts). In particular, the development of the technical interfaces is directed towards the configuration of the parts to be connected, the installation and assembly methods, the tools, the sequential criteria and the means of building. The study of the technical interfaces involves the procedures of typological identification, localization and coordination (intended as the set of "combinatory rules") implying, at methodological level:

- the development of the operational apparatus in respect of the morphological, physical, structural and executive "hierarchy" and the logic of "aggregation";
- the development of the overall and specific construction plan (by determining the methods of connection).

Moreover, the study of the technical interfaces contemplates the examination of the connection modalities with respect to the general framework of coordination, as specified by the detailed analysis regarding:

- the space defined as "functional gap", as a context of rational, logical and geometrical framing in which the relations between the components, the technical elements, the relative joining devices and the respective connection activities take place;
- the dimensional tolerances related to the production and construction phases (in addition to the tolerances related to the use of the components, technical elements and materials that build the interfaces as a whole, such as differential thermal expansion or structural adjustments) (Fig. 23).

Fig. 23. Giancarlo Marzorati, *Barceló Hotel*, Milan (©Courtesy of Giancarlo Marzorati).

The study of the technical interfaces is directed to the relational analysis carried out on the "interdependencies", on the "internal differences" and on the "organizational relations" between the parts and processes, productive and executive, involved in the "structure" of the architectural organism (whose conception consists mainly in the subdivision of the components, in the connection between the subsystems and within each subsystem). In this way, the *executive design* of the technical interfaces is part of the overall analysis of the architectural organism in systemic form, whose "organizational structure" is the condition of coordination between interdependent actions. The operability, both conceptual and practical, involves the ways of understanding and managing the interfaces between the connective sections according to:

- the conditions of "general interdependence", related to the "coordination by standardization", which means the development of rules to limit the morpho-typological, mechanical and physical performance of the components and technical elements with respect to the joining devices and connecting parts;
- the conditions of "sequential interdependence", related to the constitution and functioning of the joining devices to the components and technical elements with respect to the interface as a whole, in a specified temporal, connective and executive order;
- the conditions of "mutual interdependence", related to the performance and executive impact of one construction section with respect to another with regard to the interface (involving the adoption of the "coordination by mutual adaptation" strategy during the production and construction processes) (Fig. 24) [15].

Fig. 24. Zaha Hadid Architects, *CMA-CGM* Tower, Marseille (©Courtesy of Metalsigma Tunesi).

The development of the technical interfaces, which integrates the forecasting and timing aspects related to the effective execution criteria, is established as a procedure for anticipating and simulating the actual building site conditions. Therefore, the study implies the operational planning of the construction phases, in general, and of the "organization by sequences" of the technical interfaces, in particular: in this regard, the "organization by sequences" orders the implementation procedures of the "structural modules" according to the requirements of assembly and the connective functions between the parts of the architectural organism.

The analysis and sequential application of the technical interfaces is determined according to the subdivision of the "structural modules" in relation to the effective conditions of construction, considering:

- the development of each construction phase or sequence so that it constitutes a subset of the building process that is coherent and autonomous both temporally and spatially;
- the arrangement of the parts of the architectural organism according to the internal coordination of each subsystem of the building process and between the subsystems, taking

into account the different forms of interdependence related to the interfaces themselves.

On this basis, the processing of the technical interfaces involves both the contents and the construction tasks intended to determine the effective assembly conditions, according to the rules aimed at establishing:

- the subdivision of the connection and joining criteria by "subsystems", so that each construction sequence can constitute a coherent and independent section with respect to the application in both temporal and spatial terms;
- the development of the "assembly plans", performed with respect to the "structural modules", their technical interfaces and construction sequences, according to the production and execution phases of the components, technical elements and materials (identified in their morphological, physical, dimensional, functional and structural characteristics);
- the development of the information and indications concerning the production and executive resources, the foreseen equipment, the chronological relations of the construction contents with the reality of the building site [16].

REFERENCES

[1] C. S. Wasson, *System Engineering. Analysis, Design, and Development: Concepts, Principles, and Practices*, Wiley & Sons, New York, 2004.

[2] M. Nastri, *Téchne e poíesis. Cultura tecnologica ed elaborazione esecutiva del progetto*, FrancoAngeli, Milano, 2018.

[3] N. Elias, *The Symbol Theory*, Sage, London, 1991.

[4] D. K. Lieu, S. Sorby, *An Introduction to Visualization, Modeling, and Graphics for Engineering Design*, Delmar, Clifton Park, 2009.

[5] V. Gregotti, *Il disegno come strumento del progetto*, Marinotti, Milano, 2014.

[6] M. Nastri, *Progettazione esecutiva dell'architettura. Vol. 1. Procedure di pianificazione metodologica e di coordinamento operativo*, Tecniche Nuove, Milano, 2018.

[7] E. Robbins *et alii*, *Why architects draw*, The MIT Press, Cambridge, Mass., 1994.

[8] I. Paoletti, M. Nastri, *Material Balance. A Design Equation*, Springer, Cham, 2021.

[9] K. Frampton, *Studies in Tectonic Culture. The Poetics of Construction in Nineteenth and Twentieth Century Architecture*, The MIT Press, Cambridge, Mass., 1999.

[10] L. Rovero, S. Lanzu, *Il disegno architettonico esecutivo. Linee guida alla redazione degli elaborati grafici*, EPC, Roma, 2012.

[11] E. R. Ford, *The Architectural Detail*, Princeton Architectural Press, New York, 2011.

[12] G. E. Wiggins, *A Manual of Construction Documentation. An Illustrated Guide to Preparing Construction Drawings*, Whitney Library of Design, New York, 1989.

[13] D. Goetsch *et alii*, *Technical Drawing*, Thomson Delmar Learning, New York, 2005 5th Ed.

[14] J. Alread, T. Leslie, *Design-tech. Building Science for Architects*, Architectural Press-Elsevier, Amsterdam, 2007.

[15] R. Yee, *Architectural Drawing. A Visual Compendium of Types and Methods*, Wiley & Sons, New York, 2012.

[16] N. Meuser, *Architectural Drawings. Construction and Design Manual*, Dom, Berlin, 2015.